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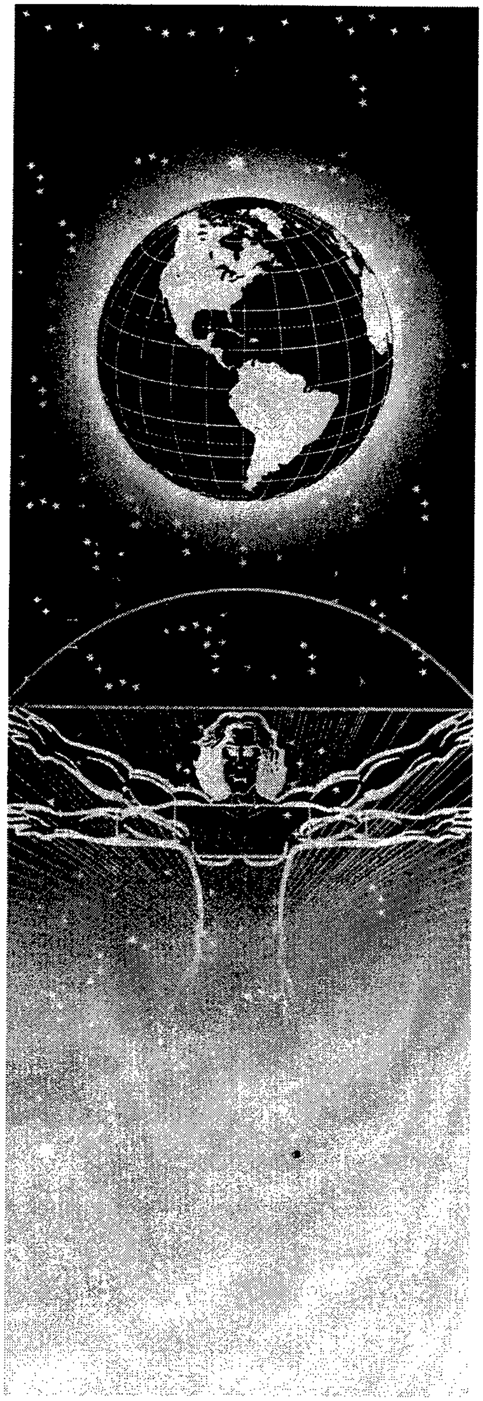

UNITED STATES AIR FORCE RESEARCH LABORATORY

Measurement of Quantitative IR Properties of Single Aerosol Particles with Emphasis On Biological and Chemical Stimulants

Richard K. Chang

Department of Applied Physics
Yale University
New Haven CT 06520

September 2004
Interim Report - June 2002 – June 2003

Human Effectiveness Directorate
Biosciences and Protection Division
Counterproliferation Branch
E5183 Blackhawk Road
Aberdeen Proving Ground MD 21010-5424

TECHNICAL REVIEW AND APPROVAL

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This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE DIRECTOR

//signed//
STEPHEN R. CHANNEL, DR-IV
Director, AF CBD Tech Base Programs
Air Force Research Laboratory

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Richard K. Chang

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Department of Applied Physics
Yale University
New Haven CT 06520

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The angular scattering pattern of θ and ϕ is sensitive to a particle's morphology (size, shape, refractive index, and surface structure). We have demonstrated that the angular pattern of the scattered light is also dependent on the absorptive part of the particle. Using numerical simulations, based on Mie's theory, we found that absorption leads to an increase in the peak-to-valley ratio in the angular scattering pattern.

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Measurement of quantitative IR Properties of Single Aerosol Particles with Emphasis on Biological and Chemical Stimulants

June 2002 to June 2003

Research Participants:

From Yale – Kevin Aptowicz, Yong-Le Pan, Mario Surbek, and Richard K. Chang

From AFRL – Burt Bronk

Elastic light scattering is being investigated as a means to extract single particle absorption. In particular, the technique labeled TAOS (Two-dimensional Angular Optical Scattering) detects the angularly resolved elastically scattered light from a particle. These TAOS patterns are sensitive to a particle's morphology (size, shape, structure, and complex refractive index) and therefore can be used to extract information on particle absorption.

Currently, the interest is to back-out absorptive information in the mid-IR wavelength regime, where there strong absorption bands arising from fundamental molecular vibrational modes of common atmospheric aerosol constituents. However, as a proof-of-concept, experiments were first performed using the second harmonic from an Nd:YAG laser (532 nm).

Using numerical simulations based on Mie theory, we found that increasing the absorption of a spherical particle leads to an increase in the peak-to-valley ratio in the detected TAOS pattern, as shown in figure 1. The experiment to test these numerical results was centered on an ellipsoidal mirror to collect a large angle of scattered light. This set-up is shown in figure 2. A triggering volume is defined by a tightly focused cw diode laser and PMT. When a particle is detected in the trigger volume, a Q-switched Nd:YAG laser is fired and the resultant laser pulse elastically scatters off of the particle. The ellipsoidal mirror reflects a solid angle greater than 2π of the scattered light to the second focal point. After propagating through a spatial filter located at the second focus, the scattered light is detected with an ICCD detector, which is also triggered by the PMT. To increase the angular resolution of the captured data only a small solid angle of the light collected by the mirror was detected on an ICCD camera. The results are displayed in figure 3. As can be seen from the results, the experiment matched fairly well with Mie theory and shows the expected increase in peak-to-valley ratio of the TAOS pattern as the absorption in increased.

In addition to collecting TAOS patterns of droplets, TAOS patterns were also collected on dry aerosol particles. This was done as a preliminary step to exam what metrics can be extracted from the patterns that could be used to extract information on particle absorption. To give further insight into the TAOS patterns, SEM (Scanning Electron Microscope) pictures were taken of these aerosols to help correlate a particle's structure and its TAOS pattern.

With this set-up, TAOS patterns were captured from a multitude of samples including albumin bovine, ammonium sulfate, Arizona road dust, Bacillus subtilis, cigarette ash, kaolin, lead tetra oxide, polystyrene latex sphere clusters, sodium chloride, soot, tobacco powder, and tryptophan. The TAOS patterns with their corresponding SEM pictures are shown in figure 4. Of particular interest is Bacillus subtilis, which is a simulant for Bacillus anthracis, the spores that cause anthrax. The features that were examined to be used as metrics were the symmetries in the pattern, the size, shape, and orientation of the speckle, and the fall-off in intensity over angle.

Mie Theory Predictions of backward scattering from an Ethanol Droplet

(Diameter = 56.22 μm, Size Parameter = 332)

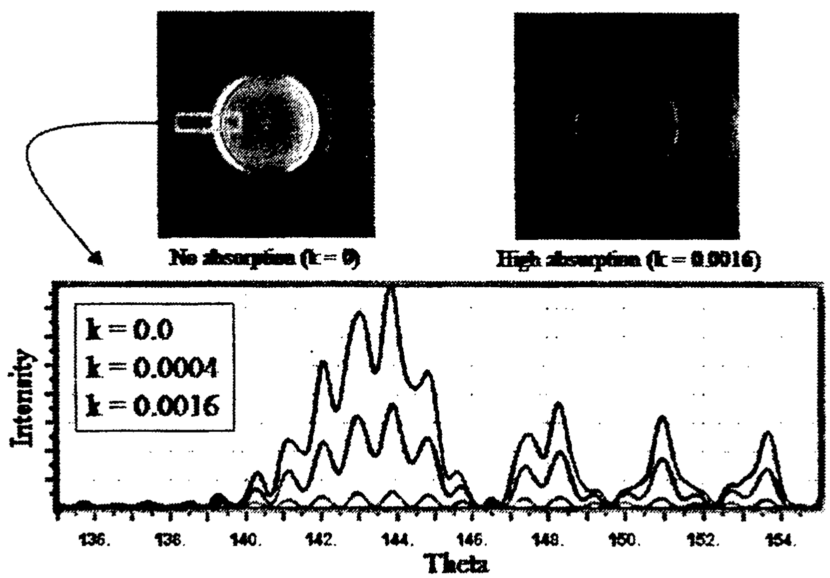

Figure 1: Mie theory prediction of the effect of increasing particle absorption on the TAOS pattern. Here, k is the imaginary part of the refractive index of the particle. To emphasize the effects, a slice has been taken out of the TAOS pattern and plotted versus intensity over Theta range 135° to 155°. Note the increase in contrast ratio as the absorption is increased.

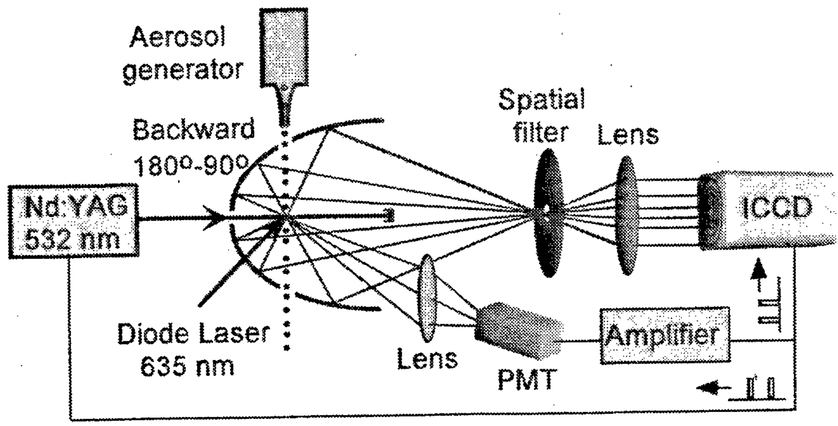

Figure 2: Experimental set-up to collect TAOS patterns in the visible.

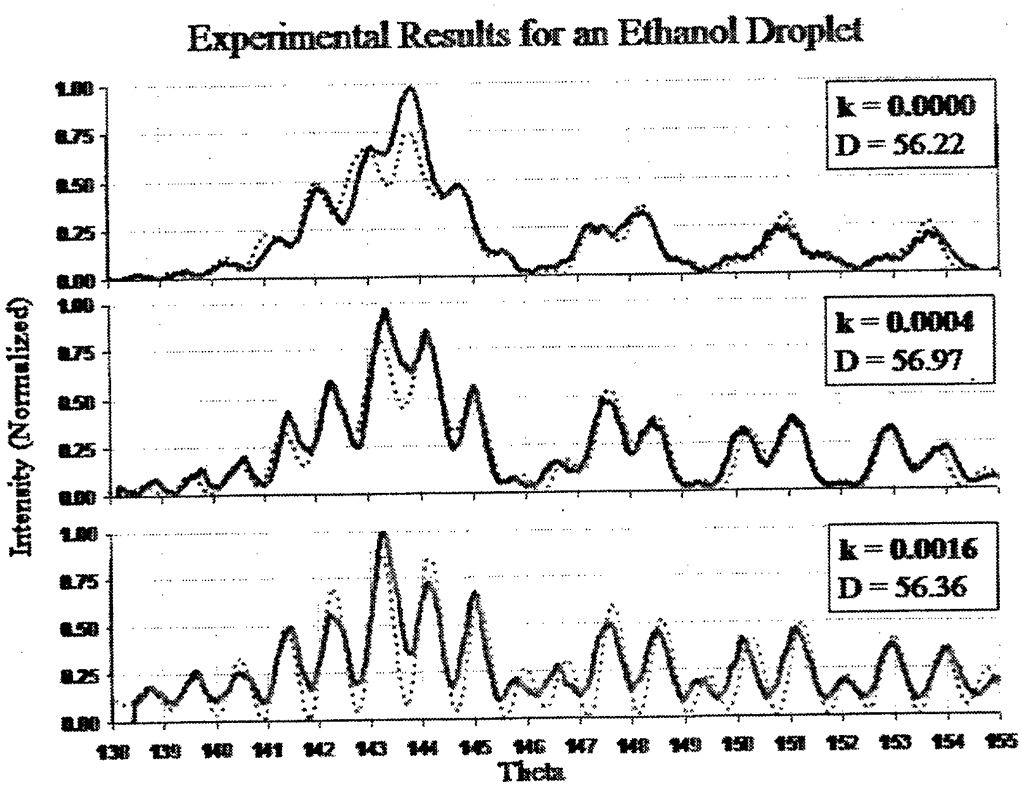

Figure 3: Experimental results (solid lines) show a good match with Mie theory predictions (dotted lines). k is the imaginary part of the refractive index and D is the diameter of the droplet in microns.

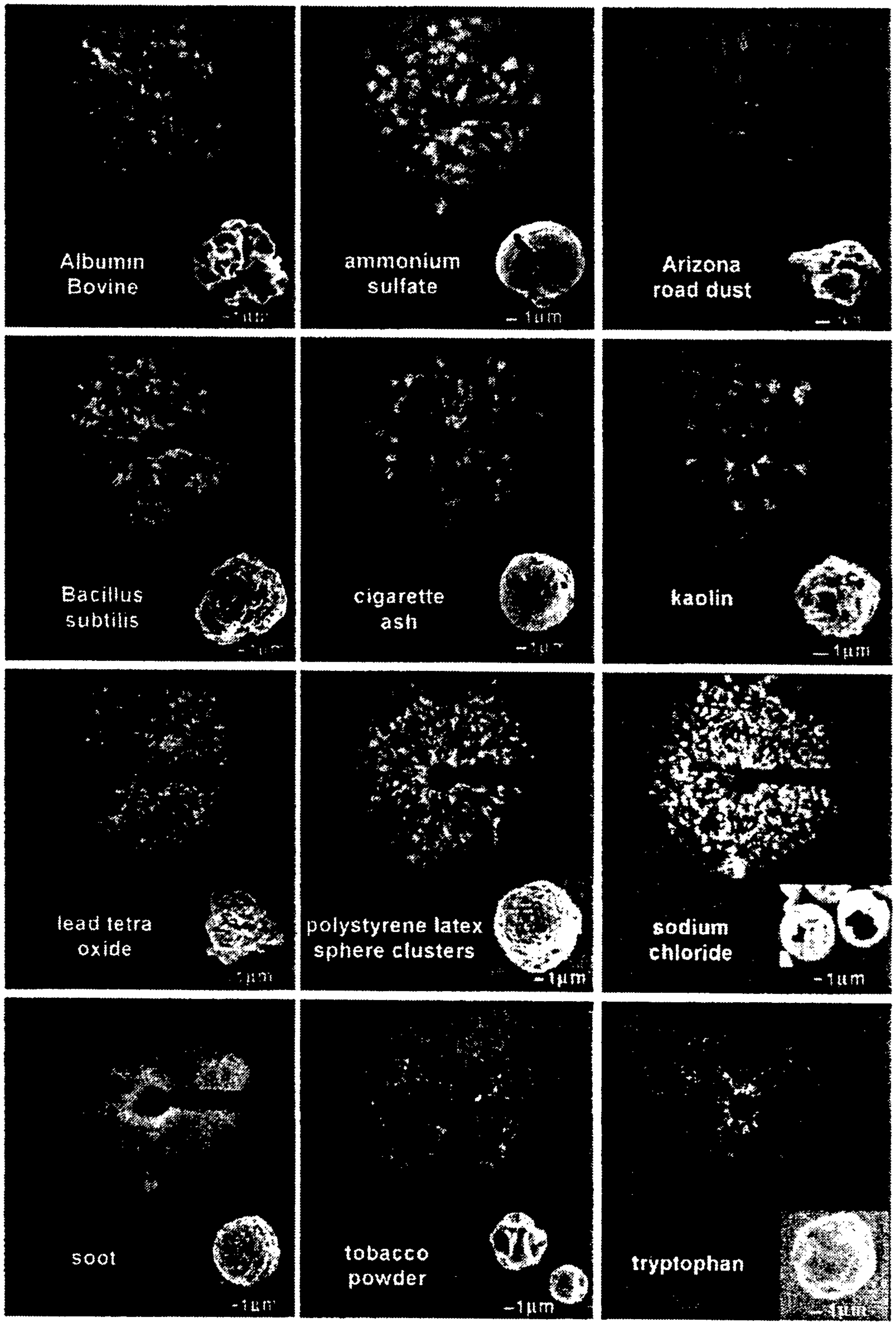

Figure 4: TAOS patterns and SEM images of the sample set. The center of the pattern would relate to the direct backward scattered light. The outer circle of the image corresponds to light scattered perpendicular to the laser axis. The black bar located on the right side of all the patterns is the beam block mount.

PUBLICATIONS

None

CONFERENCE PAPERS AND TALKS BY RICHARD K. CHANG

RAAD-Darpa-DOT Progress meeting, September 2002, Lincoln Laboratory, Lexington, MA

DOE-Review, September 18, 2002 in Savannah River Site, SC

OSA **Invited Talk,** September 29-October 4, 2002, Orlando, FL

RAAD-Darpa-DOT Progress meeting, January 28, 2003, NRL, Washington, D.C.

SUVOS-Darpa meeting in February 5-6, 2003, Dana Point, CA

Sandia National Lab, February 7, 2003, Livermore, CA

Ecole Normale Superieure, April 25, 2003, Cachan, France